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ENVIRONMENTAL CONTAMINANT LEVELS IN SHARP-SHINNED HAWKS FROM THE EASTERN UNITED STATES

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ABSTRACT.—We examined contaminant levels in tissue samples of sharp-shinned hawks (*Accipiter striatus*) collected in the eastern U.S. from 1991–93. We report concentrations of aldrin, cis-nonachlor, p,p'-DDE, dieldrin, heptachlor epoxide, mirex, oxychlordane, PCB, aluminum, lead, and mercury detected in 23 blood, 10 brain, and 31 liver samples. DDE, PCB's, and mercury were detected most often and in highest concentrations. No contaminants were present at concentrations that might cause mortality with the possible exception of one individual with high oxychlordane residues in the liver. It is not known, however, at what levels these contaminants might impair reproduction in sharp-shinned hawks. Migration count data (declining sharp-shinned hawk numbers in the East, stable in the Midwest) coupled with contaminant data (higher DDE levels in blood in eastern sharp-shins than in midwestern) do not rule out the possibility that contaminants may be impairing reproduction in the eastern population, although our data suggest that this is unlikely. Further study of contaminant levels in sharp-shinned hawks with concurrent research on their productivity and on prey availability is necessary. This species also may be an important indicator species for monitoring contaminant levels because of their high position in the food chain.

KEY WORDS: Accipiter striatus; *contaminants*; *sharp-shinned hawks*

Niveles de contaminantes ambientales en *Accipiter striatus* en el este de los Estados Unidos

RESUMEN.—Examinamos niveles de contaminación en muestras de tejido de *Accipiter striatus,* colectados al este de los Estados Unidos durante 1991 y 1993. Reportamos concentraciones de aldrin, "cis-nonachlor," PCB, aluminio, plomo y mercurio, detectadas en 23 muestras de sangre, 10 de tejido cerebral y 31 de hígado. Tanto DDE, PCB y mercurio fueron detectados más a menudo y en altas concentraciones. Sin embargo, no es conocida la concentación en los que estos contaminantes podrían dañar la reproducción en individuos de *A. striatus.* Los datos de conteos migracionales (declinación del número de *A. striatus* en el este y estabilidad en el medio-oeste) acoplados con datos de contaminantes (niveles de DDE sanguíneos mayores en *A. striatus* del este que en el medio-oeste), no descartan la posibilidad de que contaminantes puedan estar dañando la reproducción en poblaciones del Este, aunque nuestros datos sugieren que esto es improbable. Esta especie puede ser una importante indicadora para monitorear niveles de contaminación, considerando su alto nivel trófico en la cadena alimentaria.

[Traducción de Ivan Lazo]

Recently, counts of migrant sharp-shinned hawks (*Accipiter striatus*) at hawk migration watch sites in the eastern U.S. have declined, while counts conducted in the Midwest and West have remained steady or increased (Kerlinger 1992). The coastal watch site at Cape May, New Jersey began reporting declines in sharpshin counts about 1986 (Dodge 1992, Kerlinger 1992, Panko 1992). In contrast, the

mountain ridge site at Hawk Mountain Sanctuary did not note a decrease until 1990 with significant decreases occurring from 1991–93 (Laura 1992, Viverette et al. 1996). There is no indication that changes in timing or numbers of cold fronts were responsible for the declines. Numbers of sharp-shinned hawks at Hawk Mountain during the fall are not correlated with the movement or number of cold fronts (Allen et al. 1996).

Hawks banded at Cape May and Hawk Mountain have an 80% overlap in breeding range and nearly identical wintering ranges in the southeastern U.S. (Struve and Goodrich 1992, Viverette et al. 1996). Thus birds counted at the two sites are predominantly from the same population. Hawk Mountain, however, records over 60% adult sharp-shinned hawks during fall migration (Goodrich, unpubl. data), while Cape May records over 80% juveniles (Clark 1985). If sharp-shinned hawk populations were being adversely affected by poor reproduction, numbers of juveniles would decrease first, followed by declines in the adult population. Based on the closely related Eurasian sparrowhawk (*Accipiter nisus*) (Newton 1986), it is estimated that most sharp-shinned hawks may not breed until their third year (Johnsgard 1990); thus a 3–4 year delay is expected.

A similar pattern in declining counts occurred in bald eagles (*Haliaeetus leucocephalus*) when numbers of juveniles declined several years before counts of adults declined (Bednarz et al. 1990). For eagles, declines resulted because reproduction was impaired by DDT and other environmental contaminants. Perhaps contaminant exposure and impairment of reproduction may explain the reduction in sharp-shinned hawk counts at northeastern coastal watch sites several years before any reduction at other inland ridge sites.

Despite the U.S. ban on DDT in the 1970s, raptors continue to be exposed to persistent organochlorine compounds in both the U.S. and Canada (Court et al. 1990, Peakall et al. 1990, Porter 1993). Sublethal doses of contaminants in birds can and do impair reproduction (Peakall 1970). In New Jersey, Steidl et al. (1991) detected DDT-related eggshell thinning in nesting osprey (*Pandion haliaetus*) during 1985–88 and California's peregrine falcons (*Falco peregrinus*) had high egg levels of DDE throughout the 1980s (Clark 1990).

Raptors are particularly susceptible to toxic chemicals that bioaccumulate through each trophic level. Sharp-shinned hawks in particular feed high on the food chain by preying primarily on small birds (Storer 1966). Thus, they are an important species for monitoring bioaccumulation of contaminants in terrestrial systems (Elliott and Shutt 1993). Contaminant levels in sharp-shinned hawks are not well documented, particularly levels measured during recent years when population declines were observed. Noble and Elliott (1990) reported contaminant levels in eggs of sharp-shinned hawks collected in eastern Canada in 1980–88. Elliott and Shutt (1993) reported contaminant levels for sharp-shinned hawk blood samples collected in 1985–89 from two migration sites (Whitefish Point, Michigan and Hawk Cliff, Ontario) on the eastern Great Lakes. Herein, we present results from a study to examine concentrations of various environmental contaminants in blood, brain, and liver tissues of sharp-shinned hawks from the eastern U.S.

STUDY AREA AND METHODS

Blood samples were collected from 21 sharp-shinned hawks trapped on the Kittatinny Ridge in eastern Pennsylvania and at Cape May, New Jersey, during southward migration September through November 1991 and 1992. Although trapped with lure traps, they are representative of healthy, migrating sharp-shinned hawks from the eastern U.S. (Powers et al. 1994). Trapping locations are described in Clark (1985). Approximately 1 ml of blood was collected from the jugular or brachial vein with a sterile needle and syringe and immediately transferred to a heparinized vacutainer. Blood samples immediately were placed in a cooler with ice and were transported to the lab each day. Blood samples were centrifuged and the plasma was separated from the remaining blood components with a clean glass pipette. The plasma was placed into a glass vial with a lid made of inert material (teflon or aluminum), then frozen for later analysis. The amount of plasma in each sample varied from 0.01–0.65 g with most samples near 0.5 g.

Carcasses of 31 sharp-shinned hawks (19 adult, 12 juvenile) from the eastern U.S. were obtained throughout the fall and winter of 1992–93. Carcasses of sharp-shinned hawks that were killed during collisions with windows or automobiles were collected from rehabilitation centers. All carcasses were refrigerated and shipped to Hawk Mountain Sanctuary overnight on dry ice. Liver and brain tissues were removed for contaminant analyses All tissue samples were stored in a freezer and shipped frozen to the analytical laboratory on dry ice.

We analyzed 21 blood, 10 brain, and 31 liver samples from the eastern population for various compounds including aldrin, cis-nonachlor, p,p′-DDE, dieldrin, heptachlor epoxide, mirex, oxychlordane, and PCB (Table 1). We also analyzed samples for aluminum, cadmium, chromium, lead, mercury, and selenium. Not all samples were analyzed for each compound or heavy metal. Samples collected in 1992 and 1993 were tested for contaminants at Hazleton Environmental Laboratory in Madi-

Table 1. Number of samples (*N*) and values (ppm wet weight) of pesticide and heavy metal compounds analyzed in sharp-shinned hawk tissues from the eastern U.S., 1991–93. The first line of data for each compound is the number of samples with detectable levels of the contaminant and the values detected. The second line is the number of samples with values below the detection limit and the values of the detection limits.

	Blood		Brain		Liver	
Compounds	*N*	Values	*N*	Values	*N*	Values
Aldrin	0		0		0	
	13	<0.06–<4.00	8	<0.05–<0.71	9	<0.03–<0.08
Cis-nonachlor			0		2	0.40–1.60
			2	<0.10–<0.11	8	<0.04–<0.12
p,p′-DDE	16	0.02–0.49	10	0.35–15.00	31	0.17–64.00
	5	<0.09–<0.33; <4.0	0		0	
Dieldrin	0		0		8	0.10–1.20
	23	<0.01–<4.00	10	<0.05–<4.20	11	<0.07–<5.30
Heptachlor epoxide	2	0.01	0		4	0.06–1.10
	8	ND[a]	2	<0.10–<0.11	6	<0.06–<0.12
Mirex	1	0.01	0		3	0.08–0.22
	9	ND	2	<0.10–<0.11	7	<0.04–<0.12
Oxychlordane	4	0.01–0.03			10	0.01–5.21
	6	ND			0	
PCB	0		9	0.26–24.00	24	0.12–52.00
	21	<0.31–<1.70; <20	1	<0.56	2	<0.24–<0.62
t-nonachlor	7	ND				
	3	0.01–0.02				
Aluminum					12	3–476
					7	<1.58–<8.53
Cadmium					0	
					12	<1–<4
Chromium					0	
					12	<1–<4
Lead					6	0.03–0.14
					13	<0.05–<8.0
Mercury					18	0.06–2.19
					1	<0.10
Selenium					12	0.53–2.22
					0	

[a] ND = not detected.

son, Wisconsin. Samples collected in 1991 were tested at Mississippi State University Chemical Laboratory. Quality control/quality assurance procedures at both laboratories are approved by the U.S. Fish and Wildlife Service Patuxent Analytical Control Facility.

For several samples analyzed, particularly blood, contaminant levels were below detection limits (Table 1). When more than half of the samples had levels below the detection limit, we did not statistically analyze the data. When the detection limits were fairly consistent and more than one-half of the samples had detectable values, we assigned a value equal to one-half of the detection limit to samples (S. Wiemeyer, pers. comm.).

Data were transformed to common logarithms ($\log_{10}$) prior to statistical analyses. Transformed data were analyzed using student *t*-tests and analysis of variance (ANOVA) with PC version 6.4 of the Statistical Analysis System (SAS) on a microcomputer. The ANOVA model included year, gender, and an interaction term as independent variables. We used nontransformed data in Pearson product-moment correlations comparing brain and liver levels within the same individual. The significance level for all statistical tests was set at $P < 0.05$. Mean contaminant levels are presented as the arithmetic mean ($\bar{x}$) and the geometric mean (GM).

Results and Discussion

p,p′-DDE. Sixteen of 20 (80%) blood samples analyzed had measurable levels of DDE (Table 1). ANOVA showed no difference in DDE levels by gender ($F = 0.08$, $P = 0.79$), year ($F = 0.13$, $P = 0.73$), or the interaction of gender and year ($P =$

Table 2. Concentrations of p,p'DDE (ppm wet weight) in sharp-shinned hawk tissues from the eastern U.S., 1991–93

		Blood				Brain				Liver			
Age	Sex	*N*	$\bar{x}$	GM[a]	Range	*N*	$\bar{x}$	GM[a]	Range	*N*	$\bar{x}$	GM[a]	Range
Adult		13	0.21	0.16	0.04–0.49	10	6.13	2.48	0.35–15.00	19	9.98	4.56	1.04–64.00
	Female	9	0.21	0.16	0.04–0.49	6	5.53	2.33	0.35–14.00	10	13.90	6.37	1.50–64.00
	Male	4	0.21	0.19	0.09–0.35	3	9.21	4.87	0.64–15.00	7	6.77	3.95	1.04–21.00
	Unknown					1	0.47			2	1.46	1.43	1.20–1.72
Juvenile		7	0.06	0.05	0.02–0.13					12	5.41	2.15	0.17–23.81
	Female	5	0.05	0.05	0.02–0.10					5	2.79	1.19	0.17–7.30
	Male	2	0.08	0.07	0.04–0.13					6	8.36	4.05	1.30–23.81
	Unknown									1	0.89		

[a] GM = geometric mean.

0.99) for adult sharp-shins. Therefore, we combined data for adults and compared DDE levels to those found in juveniles (Table 2). Adult levels (GM = 0.16 ppm) were significantly higher than those of juveniles (GM = 0.05 ppm) (t = 3.32, P = 0.004). Similarly, Elliott and Shutt (1993) found that juvenile birds on their first southward migration had significantly lower blood plasma values of DDE than adults. They reported about 0.025 ppm (N = 20) in juvenile samples and about 0.25 ppm (N = 76) in adult samples collected from sharp-shins at Whitefish Point and Hawk Cliff on the eastern Great Lakes. Both sites are farther inland than Hawk Mountain but the breeding and wintering range of sharp-shins trapped at these sites overlaps at least 50% with ranges of birds traveling past Cape May and Hawk Mountain (Duncan 1982, Clark 1985, Struve and Goodrich 1992).

Using the regression equation (DDT in eggs = 6.243 × DDT in blood $^{1.033}$) developed by Henny and Meeker (1981), we determined that the geometric mean level of 0.16 ppm DDE in adult sharpshin blood in our study would result in an estimated 0.94 ppm in eggs (range = 0.40–2.99 ppm). This is lower than the 6.12–9.17 ug/ml reported by Snyder et al. (1973) from four sharp-shinned hawk eggs collected in New York and Pennsylvania and the 5.42–9.12 ppm in three eggs from eastern Canada reported by Meyer (1987). Meyer (1987) also reported that shell thicknesses were 23% below average. Noble and Elliott (1990) reported levels of 3.5–18.6 ppm (GM = 8.3) in 12 sharp-shinned eggs collected in eastern Canada between 1980 and 1988.

In our study, estimated egg values of 0.40–2.99 ppm were much lower than those reported for peregrine falcons (GM = 10.1 ppm) that showed only 13% eggshell thinning and were reproducing well (Ambrose et al. 1988). Fyfe et al. (1988) reported that 1.2–30 ppm DDE in eggs of birds in the genus *Falco* can impair reproduction. For Cooper's hawks (*A. cooperii*), Snyder et al. (1973) suggested that above 3–4 ppm of DDE in eggs was associated with frequent egg breakage. However, Henny (pers. comm.) suggested that accipiters can tolerate higher levels of DDE than those reported by Snyder et al. (1973). Thus, our data suggest that DDE is not impairing sharp-shinned hawk productivity in most of the individuals tested, although we do not know if sharp-shinned hawks respond at the same level of DDE as do these other species of raptors.

We analyzed brain samples from 10 adult sharp-shinned hawk carcasses recovered in the eastern U.S. All had detectable levels of DDE (Table 1) with a GM of 2.48 ppm (Table 2). Sundlof et al. (1986) reported concentrations of 0.25 and 8.50 ppm of DDE in brain tissue of sharp-shins collected in Florida in 1974 and 1977. The highest level detected in our study, 15 ppm, was considerably lower than lethal levels of brain DDE (213–301 ppm) reported in American kestrels (*Falco sparverius*) by Porter and Wiemeyer (1972) and Henny and Meeker (1981).

We analyzed liver samples from 31 sharp-shins for DDE. The highest concentration of DDE detected was 64 ppm in an adult female. DDE levels in adult liver samples were not different by gender (ANOVA: F = 1.66, P = 0.23) or year (ANOVA: F = 0.001, P = 0.96). Similarly, DDE levels in juvenile liver tissues were not different by gender (ANOVA: F = 2.64, P = 0.14) or year (ANOVA: F = 0.54, P = 0.49). The interaction of gender and year was

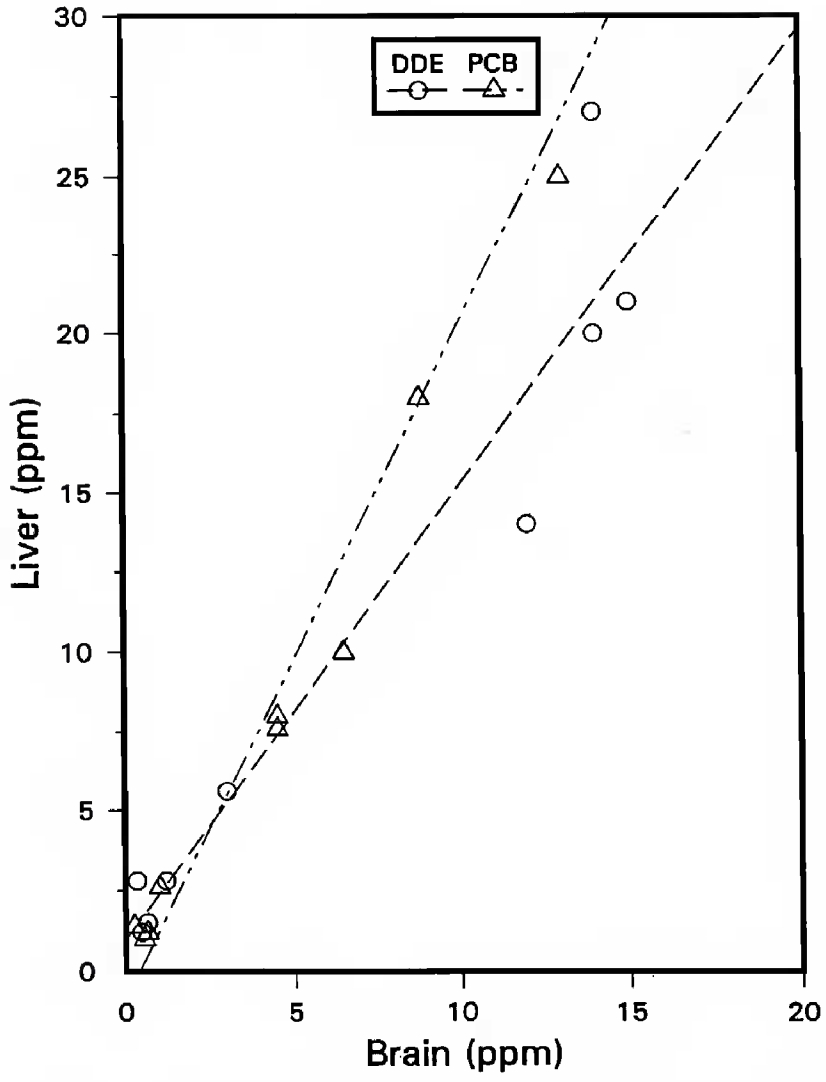

Figure 1. Relationship between eastern sharp-shinned hawk brain and liver tissue for DDE and PCB contaminant levels (ppm).

not significant for either adults ($P = 0.28$) or juveniles ($P = 0.11$). Therefore, we combined data and compared levels in adult and juvenile liver tissue. Although the average DDE level was over twice as high in adult samples (Table 2), the difference was not significant ($t = 1.55$, $P = 0.13$). Small sample size and high variability among samples likely explains this lack of significance. Sundlof et al. (1986) analyzed liver samples from two sharp-shins collected in Florida in 1971 and 1974. DDE concentrations were 0.24 and 2.10 ppm, lower than those detected in our study.

We obtained 10 brain and liver samples from the same carcass. DDE levels in the brain showed a strong and significant correlation to those in the liver ($r = 0.97$, $P = 0.0001$) (Fig. 1).

The minimum level of DDE that affects reproduction in sharp-shins is unknown, thus we do not know if DDE is playing a role in sharp-shinned hawk declines. The estimated egg DDE levels from our study are lower than those reported for earlier years (Snyder et al. 1973, Meyer 1987, Noble and Elliott 1990). In addition, DDE levels detected in birds from the eastern flyway (GM = 0.16 ppm) were higher than those measured in two sharp-shins trapped at Hawk Ridge, Minnesota (GM = 0.035 ppm) (Andersen et al. 1992), a midwestern site where sharp-shinned hawks counted on migration are remaining steady or increasing (Kerlinger 1992). Concurrent studies of contaminant levels and nesting success in eastern sharp-shinned hawks are needed to address this question.

Polychlorinated Biphenyls (PCBs). We analyzed 21 blood samples from adult sharp-shinned hawks for PCBs and none contained detectable levels (Table 1). Detection limits for the 11 samples collected in 1993 ranged from 0.31–1.70 ppm with one sample having a detection limit of 20 ppm. Detection limits were high for blood samples due to the small amount of material available for chemical analysis.

Nine of 10 brain samples from adult carcasses collected in the eastern U.S. had detectable levels of PCBs (Table 1). Values ranged from 0.26–24.00 ppm with a GM of 2.65 ppm (Table 3). Sundlof et al. (1986) reported 0.05 ppm PCB in brain tissue from a sharp-shinned hawk collected in Florida. Heinz et al. (1984) reported >300 ppm in brains of birds poisoned by PCBs, levels much higher than those found in our study. Residues in brain appear to be good indicators of PCB stress in birds (Stickel et al. 1984). It is not known, however, what levels of PCBs impair reproduction in sharp-shinned hawks.

PCBs were detected in 24 of 26 liver samples collected in our study (Table 1) with the highest level at 52 ppm (Table 3). There was no significant difference in PCB levels in adults by gender ($F = 0.95$, $P = 0.42$), year ($F = 0.37$, $P = 0.56$), or the interaction of gender and year ($P = 0.66$). Thus, we combined data and compared PCB levels in adults and juveniles. Adult levels (GM = 5.08) were not significantly higher than those in juveniles (GM = 1.6; $t = 1.98$, $P = 0.06$), possibly due to small sample size and high variability among samples.

We analyzed 10 brain and liver samples from the same carcass. PCB levels in brain tissue were highly correlated with those in liver tissue ($r = 0.99$, $P = 0.0001$) (Fig. 1).

PCBs are primarily industrial, not agricultural, pollutants. Thus, PCB residues in birds tend to be high in areas with heavy industrial use or discharge (Fleming et al. 1983, Eisler 1986). Environmental

Table 3. Concentrations of PCBs (ppm wet weight) in sharp-shinned hawk brain and liver tissues from the eastern U.S., 1991–93. Results from blood samples were not included because all values were below detection limits.

		Brain				Liver			
Age	Sex	*N*	$\bar{x}$	GM[a]	Range	*N*	$\bar{x}$	GM[a]	Range
Adult		10	6.35	2.65	0.26–24.00	16	10.30	5.08	0.86–52.00
	Female	6	5.22	2.35	0.26–13.00	9	9.35	4.66	0.86–25.00
	Male	3	10.50	5.38	1.00–24.00	6	13.24	7.36	2.60–52.00
	Unknown	1	0.64			1	1.20		
Juvenile						10	5.79	1.61	0.12–35.30
	Female					4	2.90	0.95	0.12–9.70
	Male					6	7.72	2.27	0.31–35.30

[a] GM = geometric mean.

contamination resulted from industrial discharges, improper disposal of PCB wastes to municipal sewage treatment plants or landfills and dumps, and especially through atmospheric transport of incompletely incinerated PCBs (Eisler 1986). Freshwater sediment is a major terrestrial reservoir for PCBs (Eisler 1986). Although the levels of PCBs we found in sharp-shinned hawks probably are not affecting the health of these birds, they do seem elevated for terrestrial birds (L. Shutt, S. Wiemeyer, pers. comm.).

Other Organochlorine Pesticides. Aldrin was not detected in any of the samples tested from the eastern sharp-shinned hawk population and detection limits were low (Table 1). Cis-nonachlor was detected in two of 10 liver samples tested. Detection limits for the eight remaining liver samples and two brain samples were low. Similarly, heptachlor epoxide was detected at low levels in four of 10 liver samples and two of 10 blood samples with low detection limits for the remaining two blood, six liver, and two brain samples. Mirex was detected in only three of the 10 liver samples and one blood sample; detection limits of the remaining samples were low. Low detection limits of these contaminants indicate that they were present only in low levels, if at all.

All 10 liver samples tested for oxychlordane had detectable levels ranging from 0.01–0.72 ppm (wet wt), with one individual at 5.21 ppm. The lethal hazard zone for brain tissue begins at 5 ppm (Stickel et al. 1979). Acute toxicity has occurred in predatory birds at 3–10 ppm in liver (Cooke et al. 1982). Sublethal effects of this chemical are not known, nor at what levels sublethal effects occur. Although used widely in the past (Eisler 1990), the only current legal use of chlordane in the U.S. is for fire ant control in power plants (Briggs 1992). Thus, sharp-shinned hawks wintering in the southern U.S. could be exposed to this organochlorine compound. With the spread of fire ants across the southern U.S., there is increasing pressure to allow greater use of chlordane. Sharp-shinned hawks are an ideal species for monitoring bioaccumulation of chlordane in terrestrial systems.

Dieldrin was not detected in blood or brain samples (Table 1). Only 8 of 19 liver samples had detectable levels of dieldrin with a mean of 0.35 ppm (GM = 0.25 ppm). Detection limits for dieldrin in brain and liver tissue were sometimes elevated because the PCB signals peaked in the same area of the chromatogram interfering with identification of dieldrin (T. Noltemeyer, Hazleton Environmental Services, pers. comm.).

Mercury. Mercury was detected in 18 of 19 liver samples analyzed in this study (Table 1). Mercury levels in adult liver samples (Table 4) collected in 1991 (GM = 0.98 ppm) were significantly higher ($t = 6.20$, $P < 0.0001$) than those collected in 1993 (GM = 0.12 ppm). The samples from each study were analyzed by different laboratories; thus, the difference we saw may be due to differences in methods or equipment sensitivity of the two laboratories. Both levels of mercury, however, were well below levels (>20 ppm) of mercury residues found in tissues of other birds that died of mercury poisoning (Finley et al. 1979). In a review of mercury studies on birds, Ohlendorf (1993) found that <1–10 ppm of mercury in liver was considered a normal background level for birds in general, while >6 ppm was considered toxic.

Other Metals. Aluminum was not detected in

any of the 1993 liver samples tested but detection limits were high. Aluminum was found in the 1991 samples ranging from 3–22 ppm with one sample at 476 ppm. Selenium was detected at low levels in 12 liver samples analyzed, while cadmium and chromium were not detected in any of the samples. Low detection limits for these metals indicate that they were present in very low levels, if at all.

Lead was detected in six of seven liver samples collected in 1993 (Table 1) with a mean concentration of 0.07 ppm wet wt (GM = 0.06). The 1991 liver samples had no detectable levels of lead in 12 liver samples; however, detection limits were much higher than those in 1993 ranging from 2.0–8.0 ppm. Lead levels found in our study likely are not detrimental to sharp-shinned hawks. Ohlendorf (1993) reviewed studies that suggested <0.5–5.0 ppm (dry weight) of lead in liver tissues for various bird species can be considered representative of background levels.

SUMMARY

DDE, PCBs, and mercury were detected most often and in highest concentrations in the sharp-shinned hawks we sampled. No contaminants were present at concentrations that might cause outright mortality with the possible exception of one individual with high oxychlordane residues in the liver. Most samples had low concentrations of contaminants. It is not known, however, at what levels these contaminants might impair reproduction in sharp-shinned hawks. Migration count data (declining sharp-shinned hawk numbers in the East, stable in the Midwest) coupled with contaminant data (higher DDE levels in blood in eastern sharp-shins than in midwestern) do not rule out the possibility that contaminants may be impairing reproduction in some individuals from the eastern population. However, our data are inconclusive regarding effects on the eastern population as a whole because of a lack of concurrent data on reproduction and contaminant levels.

Although our data are inconclusive, they suggest some interesting avenues for further research. Why does the eastern population of sharp-shinned hawks have higher contaminant levels than the midwestern population? How does this terrestrial bird bioaccumulate PCBs, an aquatic contaminant? Further, because of a lack of data for contaminant levels in sharp-shinned hawks, our results provide comparative data for future monitoring of contaminants in these birds.

Elliott and Shutt (1993) postulated that sharp-shins were exposed to pesticide contaminants on southern wintering grounds, both in the southern U.S. and in Central and South America. They found that juvenile birds left the Canadian breeding grounds with low contaminant levels and returned the next spring with the same levels as adults. Similarly, we found lower levels in juveniles than in adults. Banding data from eastern Great Lakes sites indicate that part of their sharp-shin population winters in Latin America, while banding data from the East show that the majority of sharpshins on the eastern flyway winter in southeastern states and rarely leave the continental U.S. (Clark 1985, Struve and Goodrich 1992).

Pesticide use in Latin America continues to have a significant effect on bird populations (Risebrough 1986) as does use of some pesticides (e.g., chlordane) in the U.S. Sharp-shinned hawks feed mainly on small birds, with neotropical migrants comprising about a third of the diet (Storer 1966). Consequently, sharp-shins likely are exposed to contaminants by consuming contaminated prey both on their wintering and breeding grounds. Further study of contaminant levels in sharp-shinned hawks with concurrent research on prey availability and productivity is necessary.

Sharp-shinned hawks may be a good indicator species for monitoring contaminants in terrestrial systems. Recent pressure to increase use of chlordane for fire ant control in the southern U.S. makes it essential to monitor for this contaminant.

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